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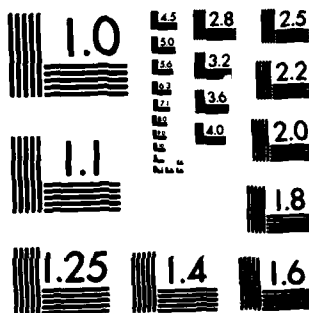
BATHYMETRIC MEASUREMENT AT PHELPS BANK(U) NAVAL 1//
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An NRL remote sensing experiment was conducted in July 1982 to measure ocean surface manifestations of subsurface topography and hydrography. The central topographic feature of the operational area was Phelps Bank (40° 50' N - 69° 20' W). This report presents the bathymetric contour of the bank based on 6 ship crossings (USNS HAYES).		

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BATHYMETRIC MEASUREMENTS AT PHELPS BANK

INTRODUCTION

From July 5-25, 1982 scientists from NRL and other laboratories conducted a cooperative remote sensing experiment. The general purpose of the experiment was to obtain information on oceanographic processes responsible for the surface expression of bathymetry (SEBEX) and hydrography in the wave field and radar imagery of relatively shallow seas. To this end simultaneous and coordinated remote sensing, oceanographic, meteorological hydrographic and bathymetric measurements were made. The overall plan of the field exercise was under the direction of Dr. Davidson Chen (NRL Code 7912C) and Dr. Gaspar Valenzuela (NRL Code 4305). Mr. William Garrett (NRL Code 4333) served as senior scientist aboard the USNS HAYES.

BACKGROUND

Probably the first investigators to report that radar imagery of the surface waves of shallow seas included features that were related to the bottom topography were DeLoor and Brunsveld van Hulten (1978). The phenomenon has been treated in some detail in DeLoor's more recent work (DeLoor 1981). The bottom topography effect has been particularly noticeable in SAR (synthetic aperture radar) imagery from the SEASAT satellite (English channel and Nantucket Shoals) although airborne SAR and SLAR (side-looking airborne radar) also show the effect. McLeish et al (1981) have published an interpretation of SLAR imagery of surface wave patterns in the North Sea which are related to sea-floor topography. A general review of the topic may be found in the recent book "Spaceborne synthetic aperture radar for oceanography" Beal et al eds (1981).

Manuscript approved October 1, 1982.

The overall plan of the NRL Remote Sensing Experiment has been submitted for publication by Valenzuela (1981) and a review of surface effects attributable to subsurface processes has been published by Chen (1982).

FIELD MEASUREMENTS

The site chosen as the central point for the NRL Remote Sensing Experiment was Phelps Bank. The bank is a relatively isolated, subsurface, topographic feature located approximately 37 nautical miles southeast of Nantucket Island (40°50'N-69°20'W). No specific provisions were made in the operational plan for detailed bathymetric measurements of Phelps Bank, however, on a few occasions, the cruise track of the USNS HAYES did inadvertently pass over the bank. Since the depth was recorded continuously on a shipboard sonic fathometer and navigational data (LORAN-C positions) were recorded each minute during the entire operation, the information required to obtain topographic contours of the bank was available. Furthermore, on one occasion, the USNS HAYES was deliberately drifted across Phelps Bank for the purpose of recording a bathymetric contour.

The present report is a collection and interpretation of the available bathymetric data recorded in the vicinity of Phelps Bank during the USNS HAYES cruise of July 1982. Needless to say, a detailed description of the topography of the bank is required for any future modeling of remotely-sensed, dynamically-induced surface effects associated with this subsurface feature. This preliminary study is motivated by that need.

The USNS HAYES operated in the general area of Phelps Bank for about 10 days. During that time there were 6 passes over the bank on 5 different days: July 11, 14 (2 crossings), 19, 20, 21, 1982. The bathymetric

and navigational data recorded during these crossings are listed in the table. The LORAN-C coverage in the area is exceptionally good. Estimates based on the consistency of LORAN fixes indicate that one minute-averaged, relative positions are accurate to within about 200-300 ft. (60-90 m). The depth soundings were made with a 12 KHz fathometer (EDO Western Corp. 258-E transducer and Raytheon LSR-1811 recorder) which has a nominal 30° beam width. Errors in these measurements are estimated to be about 1 meter and are primarily attributable to vertical ship motion, unresolved bottom fine structure and tidal variation.

The data from the table are plotted in Figure 1 which shows the six ship tracks and the contours resulting from interpolation and interpretation of the depth measurements along the tracks. Figure 2 presents the East-West profiles of Phelps Bank along tracks A-E. This figure includes some additional bathymetric detail obtained from the original fathometer records. In particular, Figure 2 shows large sand waves that may be missed by the grid spacing recorded in the table.

Of the six ship tracks only B was a deliberate, cross-bank measurement. This drifting course was planned as an experiment to produce a detailed bathymetric profile of the bank in the vicinity of a current-meter mooring and to establish how the current flow varies as it passes over the bank. The latter assumes that the USNS HAYES acts as a Lagrangian drifter when all engines are stopped. Because track B was part of a planned operation, the timing and depth measurements were monitored continuously. For this reason track B is considered the "baseline" for the bathymetry. For the other tracks the fathometer was time checked only intermittently by various watch standers and interpolations based on calculated recording

chart speeds were used to determine the depth-time relationships. Track B progressed from East to West at a drift speed of approximately 1.5 kt (0.77 m sec^{-1}).

Track A also proceeded from East to West and was essentially in a drifting mode. The only ship maneuvers during Track A were to maintain slack-line conditions on a tethered buoy that was deployed at the time. The track passed over the southern end of the bank in an area referred to as Asia Rip on the navigational charts (NOAA 1979) at drift speeds ranging from 1.5 to 3.4 kt ($0.77\text{--}1.75 \text{ m sec}^{-1}$).

While traversing the other four tracks (C-F) the USNS HAYES was under power. Tracks C and E represent ship travel from West to East at speeds of 8.7-9.6 kt ($4.5\text{--}4.9 \text{ m sec}^{-1}$) and 1.5-4.0 kt ($0.77\text{--}2.06 \text{ m sec}^{-1}$) respectively. During Track D the HAYES was moving East to West at speeds ranging from 7.6-8.5 kt ($3.9\text{--}4.4 \text{ m sec}^{-1}$). Track F depicts a South to North course at speeds between 4 and 6 kt ($2\text{--}3 \text{ m sec}^{-1}$).

Of the six tracks only one (Track C) required post-recording adjustment. This track was adjusted such that the depth was consistent at a known position, that is, where Track C crossed Track B, the "base-line" track. This adjustment consisted of an approximately 5-minute time change and it was assumed that the time mark put on the bathmetry record by the watch stander was in error. The data from all the other tracks were plotted without adjustment or correction.

DISCUSSION

The most striking feature of the Phelps Bank profile (Fig. 1 and 2) is its asymmetry. This result is rather surprising in view of the fact that the currents in the area are dominated by rotary tides, which are

relatively symmetrical. The slope of the bank rises slowly on the seaward side (0.3° slope) but falls considerably faster (5.7° slope) on the landward side. Apparently this asymmetry is characteristic of shoals in this general area. A study by Jordan (1962) of Cultivator Shoal and Georges Shoal on Georges Bank approximately 80 miles northeast of Phelps Bank also noted steeper western slopes on these shoals. He found that the western slope of Georges Shoal has a gradient of 6° , in close agreement with our measurements of Phelps Bank.

The steeper landward slopes suggest a westerly movement of the shoals but of indeterminate time scale. Without supporting sequential bathymetric data taken over a number of years, there is no clear way to demonstrate this effect. In general it is considered that an asymmetrical shape in a bed form such as a large sand wave is an indicator of the direction of sediment motion (Jordan 1962, Dingle 1965) whereas a symmetrical sand wave is assumed to be stationary. For example, when Jordan (1962) measured sand waves in the Columbia river, spaced the order of 90 m with amplitudes as large as 4.5 m, he found upstream slopes of 2° as contrasted to downstream slopes of 16° . Some of the sand waves measured by Dingle (1965) in the North Sea were 1200 m long, 14 m high and showed considerable asymmetry. For the smaller bed forms (100 meter wavelength x 3 m amplitudes) such as subsurface sand dunes Smith (1970) has proposed a mechanism in which migration of the larger form is accomplished by the motion of superimposed, smaller forms which are transported faster and ultimately falls down the lee slope of the larger form. The presence of non-symmetrical sand waves superimposed on Phelps Bank (Fig. 2) is consistent with this kind of sediment transport. However, this mode of sand movement is usually encountered

where there is a general flow in one direction. Smith (1969) has also published a theory for the maintenance of large scale sand ridges parallel to the long axis of rotary tidal currents, a dynamic situation more similar to that in the Phelps Bank area, where the flow is dominated by rotary tides (NOAA 1981). Any detailed study of the geomorphology of Phelps Bank will require extensive bathymetric and current measurements in the Nantucket Shoals area and is beyond the scope of this report.

It should be noted that these measurements indicate that Phelps Bank is somewhat deeper than is shown on the navigational charts presently in use (NOAA 1979). The depths marked on the charts range from 10.5-12.8 m whereas on the 6 tracks recorded during this exercise the shallowest depth measured was 18 m. It is possible but unlikely that there are peaks of 5-8 m superimposed on topography shown in Fig. 1. More detailed measurements during the follow-on SEBEX program will resolve this question.

ACKNOWLEDGMENT

The authors express their appreciation to Dr. J.A.C. Kaiser for providing most of the meteorological and navigational records used in preparation of this report. Helpful discussions with Mr. J.H. Ostrander, NRL navigator, are also gratefully acknowledged.

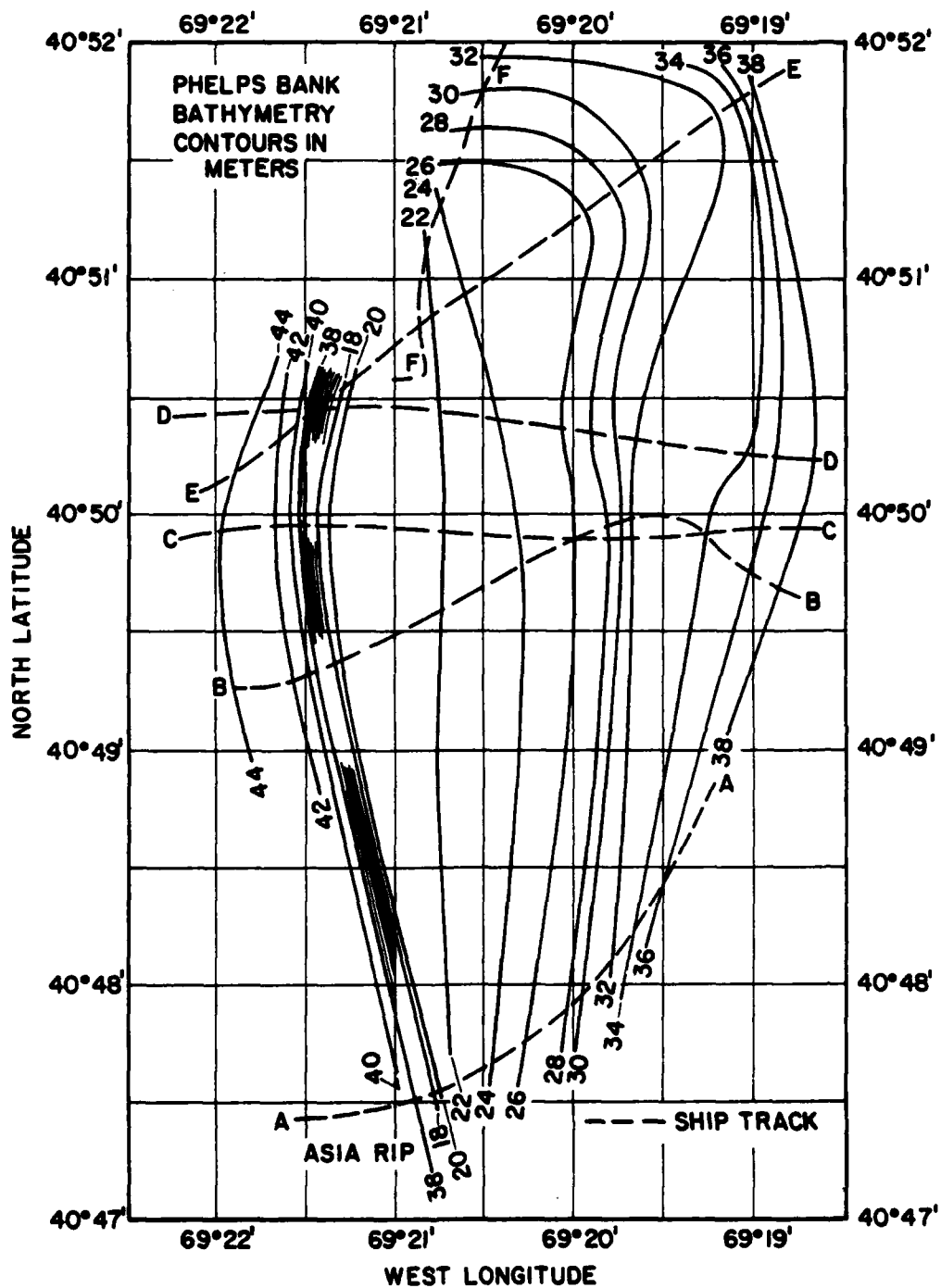


Fig. 1 — Bathymetric contour of Phelps Bank based on the six ship tracks (A-F) shown as dashed lines

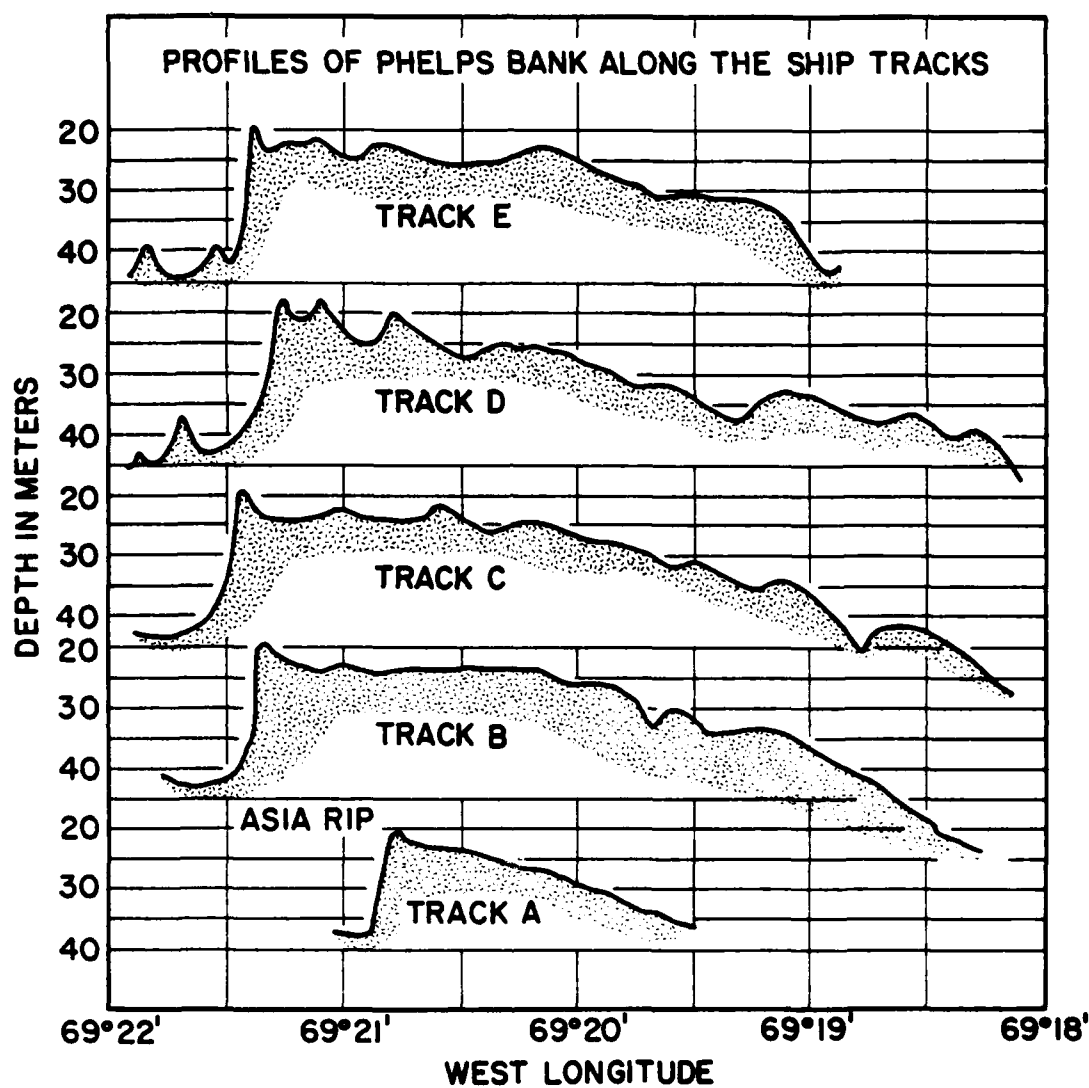


Fig. 2 — Profiles of the bank along ship tracks A-E (Fig. 1) showing the presence of sand waves and an overall East-West asymmetry. The vertical scale is exaggerated $\times 36$.

Table: Phelps Bank Bathymetry

Track A (July 14, 1982)

Time (U.T.)	Depth (M)	N. Latitude	W. Longitude
1420	36.0	40° 48.45'	69° 19.49'
1422	35.5	40° 48.34'	69° 19.57'
1424	34.0	40° 48.25'	69° 19.65'
1426	33.0	40° 48.17'	69° 19.73'
1428	31.0	40° 48.11'	69° 19.82'
1430	30.5	40° 48.04'	69° 19.90'
1432	29.5	40° 47.97'	69° 19.97'
1434	28.5	40° 47.91'	69° 20.04'
1436	27.5	40° 47.85'	69° 20.12'
1438	26.5	40° 47.80'	69° 20.21'
1440	25.5	40° 47.75'	69° 20.31'
1442	24.5	40° 47.70'	69° 20.40'
1444	24	40° 47.65'	69° 20.49'
1446	23.5	40° 47.61'	69° 20.58'
1448	23.5	40° 47.57'	69° 20.67'
1450	22.5	40° 47.52'	69° 20.76'
1451.5	21.0		
1452	24.0	40° 47.50'	69° 20.82'
1454	38.0	40° 47.48'	69° 20.89'
1456	37.5	40° 47.49'	69° 20.99'

Track B (July 21, 1982)

0929	43.0	40° 49.65'	69° 18.69'
0931	39.0	40° 49.71'	69° 18.93'
0933	34.0	40° 49.79'	69° 19.12'
0935	33.5	40° 49.90'	69° 19.24'
0937	34.5	40° 49.99'	69° 19.45'
0939	30.0	40° 50.01'	69° 19.57'
0941	32.0	40° 49.99'	69° 19.67'
0943	29.0	40° 49.96'	69° 19.74'
0945	28.0	40° 49.93'	69° 19.82'
0947	25.5	40° 49.91'	69° 19.90'
0949	26.0	40° 49.89'	69° 19.97'
0951	25.0	40° 49.88'	69° 20.04'
0953	24.0	40° 49.87'	69° 20.13'
0955	24.0	40° 49.84'	69° 20.21'
0957	23.5	40° 49.81'	69° 20.26'
0959	23.5	40° 49.77'	69° 20.32'
1001	23.0	40° 49.74'	60° 20.39'
1003	23.0	40° 49.71'	60° 20.45'
1005	23.0	40° 49.69'	60° 20.52'
1007	23.5	40° 49.66'	60° 20.60'
1009	23.5	40° 49.63'	60° 20.65'

Table (Cont'd): Phelps Bank Bathymetry

Track B (Cont)

Time (U.T.)	Depth (M)	N. Latitude	W. Longitude
1011	23.5	40° 49.61'	69° 20.71'
1013	24.0	40° 49.59'	69° 20.77'
1015	23.5	40° 49.58'	69° 20.82'
1017	24.5	40° 49.55'	69° 20.87'
1019	23.5	40° 49.52'	69° 20.94'
1021	22.5	40° 49.50'	69° 20.98'
1023	22.0	40° 49.49'	69° 21.03'
1025	23.5	40° 49.48'	69° 21.10'
1027	24.5	40° 49.45'	69° 21.16'
1029	23.0	40° 49.42'	69° 21.20'
1031	23.5	40° 49.41'	69° 21.24'
1033	22.5	40° 49.41'	69° 21.28'
1035	18.4	40° 49.40'	69° 21.33'
1037	31.5	40° 49.37'	69° 21.37'
1039	37.0	40° 49.36'	69° 21.41'
1041	38.5	40° 49.35'	69° 21.42'
1043	39.5	40° 49.34'	69° 21.46'
1045	40.5	40° 49.33'	69° 21.49'
1047	41.5	40° 49.32'	69° 21.52'
1049	41.0	40° 49.32'	69° 21.54'
1051	41.5	40° 49.32'	69° 21.55'
1053	41.5	40° 49.31'	69° 21.58'
1055	42.0	40° 49.29'	69° 21.59'
1057	41.5	40° 49.30'	69° 21.61'
1059	42.0	40° 49.30'	69° 21.63'

Adjusted Track C (July 14, 1982)

1715	44.5	40° 49.89'	69° 22.48'
1716	44.0	40° 49.91'	69° 22.31'
1717	43.0	40° 49.93'	69° 22.15'
1718	43.0	40° 49.94'	69° 21.94'
1719	43.0	40° 49.96'	69° 21.73'
1720	39.0	40° 49.97'	69° 21.53'
1720.5	19.5		
1721	23.5	40° 49.97'	69° 21.33'
1722	24.0	40° 49.95'	69° 21.15'
1723	23.0	40° 49.95'	69° 20.95'
1724	24.0	40° 49.94'	69° 20.76'
1725	22.0	40° 49.93'	69° 20.57'
1726	26.5	40° 49.91'	69° 20.37'
1727	24.0	40° 49.91'	69° 20.18'
1728	26.5	40° 49.90'	69° 19.98'
1729	28.0	40° 49.91'	69° 19.78'
1730	30.5	40° 49.91'	69° 19.57'
1731	31.0	40° 49.92'	69° 19.39'

Table (Cont'd): Phelps Bank Bathymetry

Adjusted Track C (Cont)

1732	35.5	40° 49.93'	69° 19.19'
1733	35.0	40° 49.94'	69° 19.00'
1734	41.0	40° 49.94'	69° 18.81'
1735	42.5	40° 49.95'	69° 18.60'

Track D (July 19, 1982)

1530	48.0	40° 50.18'	69° 18.10'
1531	39.0	40° 50.20'	69° 18.28'
1532	39.0	40° 50.22'	69° 18.47'
1533	38.0	40° 50.23'	69° 18.65'
1534	37.0	40° 50.25'	69° 18.82'
1535	34.0	40° 50.25'	69° 19.00'
1536	33.0	40° 50.27'	69° 19.17'
1537	37.0	40° 50.29'	69° 19.35'
1538	34.0	40° 50.31'	69° 19.53'
1539	32.0	40° 50.32'	69° 19.69'
1540	29.0	40° 50.35'	69° 19.87'
1541	27.0	40° 50.36'	69° 20.04'
1542	25.0	40° 50.38'	69° 20.20'
1543	25.0	40° 50.39'	69° 20.37'
1544	26.5	40° 50.41'	69° 20.54'
1545	22.0	40° 50.43'	69° 20.72'
1545.3	19.5		
1546	25.0	40° 50.44'	69° 20.89'
1547	21.0	40° 50.47'	69° 21.07'
1547.3	18.0		
1548	21.0	40° 50.46'	69° 21.24'
1548.2	18.0		
1549	37.5	40° 50.45'	69° 21.43'
1550	43.0	40° 50.44'	69° 21.62'
1551	45.0	40° 50.43'	69° 21.81'
1552	45.0	40° 50.43'	69° 22.00'
1553	45.0	40° 50.42'	69° 22.19'
1554	43.0	40° 50.41'	69° 22.38'
1555	44.0	40° 50.40'	69° 22.56'
1556	42.0	40° 50.39'	69° 22.75'

Track E (July 11, 1982)

1339	43.5	40° 50.25'	69° 21.79'
1341	43.0	40° 50.33'	69° 21.64'
1343	42.0	40° 50.42'	69° 21.49'
1345	24.0	40° 50.50'	69° 21.35'
1345.5	19.0		
1347	22.0	40° 50.58'	69° 21.20'
1347.5	19.5		
1349	23.0	40° 50.67'	69° 21.08'
1351	25.0	40° 50.74'	69° 20.94'
1352.5	18.5		

Table (Cont'd): Phelps Bank Bathymetry

Track E (Cont)

1353	22.0	40° 50.82'	69° 20.82'
1355	24.5	40° 50.89'	69° 20.69'
1357	25.5	40° 50.97'	69° 20.55'
1359	25.0	40° 51.04'	69° 20.41'
1401	24.5	40° 51.11'	69° 20.28'
1403	22.0	40° 51.17'	69° 20.16'
1405	24.0	40° 51.23'	69° 20.06'
1407	25.5	40° 51.29'	69° 19.95'
1409	27.0	40° 51.34'	69° 19.85'
1411	28.5	40° 51.40'	69° 19.74'
1413	31.0	40° 51.46'	69° 19.64'
1415	30.5	40° 51.52'	69° 19.53'
1417	31.0	40° 51.58'	69° 19.42'
1419	30.5	40° 51.63'	69° 19.31'
1421	31.5	40° 51.67'	69° 19.23'
1423	33.0	40° 51.73'	69° 19.15'
1425	34.0	40° 51.74'	69° 19.10'
1427	37.0	40° 51.78'	69° 19.03'
1429	41.0	40° 51.81'	69° 18.97'
1431	44.0	40° 51.84'	69° 18.93'
1433	42.0	40° 51.86'	69° 18.88'
1435	42.0	40° 51.88'	69° 18.84'

Track F (July 20, 1982)

2325	25.5	40° 50.57'	69° 20.96'
2326	26.0	40° 50.57'	69° 20.92'
2327	26.0	40° 50.59'	69° 20.86'
2328	20.5	40° 50.66'	69° 20.84'
2329	20.5	40° 50.74'	69° 20.86'
2330	18.0	40° 50.84'	69° 20.86'
2331	19.0	40° 50.94'	69° 20.88'
2332	20.5	40° 51.03'	69° 20.88'
2333	21.5	40° 51.13'	69° 20.83'
2334	22.5	40° 51.21'	69° 20.79'
2335	24.0	40° 51.31'	69° 20.75'
2336	25.0	40° 51.40'	69° 20.70'
2337	26.0	40° 51.49'	69° 20.65'
2338	28.0	40° 51.59'	69° 20.60'
2339	29.0	40° 51.68'	69° 20.56'
2340	30.0	40° 51.77'	69° 20.51'
2341	31.0	40° 51.87'	69° 20.47'
2342	33.0	40° 51.96'	69° 20.41'
2343	34.0	40° 52.06'	69° 20.38'
2344	36.0	40° 52.15'	69° 20.34'
2345	37.0	40° 52.52'	69° 20.29'
2346	39.0	40° 52.34'	69° 20.24'

NOTES FOR TABLES

- (1) Track C was adjusted by 5 minutes for consistency with a known depth measurement on Track B. There was apparently an error in time notation on the PDR (bathymeter) record. On Track C there are 7-8 m sand waves 1715-1719 and 3-4 m sandwaves 1721-1724.
- (2) On Track D there are 2-6 m sandwaves 1530-1544 and 6-7 m sandwaves 1550-1556.
- (3) On Track E there are 7 m sandwaves 1337-1342.
- (4) On Track F there are 5-6 m sandwaves 2338-2346.

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